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Evaluation of DOD Priority Species At Risk (SAR) and Applications for Remote Sensing

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Abstract: The presence of species on military training lands that could potentially be listed as threatened or endangered as defined under the Endangered Species Act as Species at Risk (SAR) may result in increased training restrictions if they were to be listed. Accurate and repeatable remote sensing methods in combination with field surveys are required to quantify the presence, and to characterize and monitor the spatial extent of SAR or their habitats on military lands. A list of DOD priority SAR species that have greatest potential to impact the training mission were assessed to identify and prioritize those with greatest potential for detection, mapping, and monitoring with remotely sensed data. Seven species were identified with greatest potential, and a prototype plan for research case studies to acquire, analyze, and validate remote sensing methods to detect, map, and monitor such species was provided.

Table of Contents

List of Figures and Tables

Figure **Page**

Table **Page**

Table **Page**

Preface

This study was conducted for the Construction Engineering Research Laboratory (ERDC-CERL) under "Training Lands Management – Characterization, Analysis, and Mitigation," under program element A896, "Army Environmental Quality Technology"; Work Unit GBBC80, "Hyperspectral Remote Sensing." The CERL technical monitor was Dr. William Severinghaus, Technical Director, Sustainable Ranges and Lands.

The work was performed by three ERDC laboratories: Topographic Engineering Center, Cold Regions Research and Engineering Laboratory, and Construction Engineering Research Laboratory. Scott A. Tweddale was ERDC-CERL Principal Investigator. Dr. Timothy Hayden is Program Manager of the Habitat-centric Species-At-Risk (SAR) Research to Avoid Future Training Restrictions Program. Alan Anderson is Chief, Ecological Processes Branch (CN-N) of the Installations Division (CN), and Dr. John Bandy is Chief, CN. The Deputy Director of CERL is Dr. Kirankumar V. Topudurti, and the Director of CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Gary E. Johnston, and the Director of ERDC is Dr. James R. Houston.

1 Introduction

Background

The Department of Defense (DoD) maintains more than 700 individual facilities throughout the 50 United States, seven U.S. territories, and 39 foreign countries worldwide (DoD 2007). The estimated total land holdings worldwide is over 32 million acres (~ 13 million ha). Many of the facilities within the United States have been characterized as having disproportionately high values in terms of biodiversity when compared to other Federally managed and privately owned lands (Leslie 1996). In addition, these facilities provide habitat for many Federally listed threatened and endangered species, or Species at Risk (SAR). SAR are plant and animals that are not yet Federally listed as threatened or endangered species as defined under the Endangered Species Act, but that are candidates for listing (NatureServe 2004).

This can present a difficult challenge for natural resource management activities on DoD installations, which must develop and implement land management strategies that adhere to a broad array of environmental regulations, including management of habitat to sustain or recover listed species, while sustaining the primary mission of providing a suitable landscape for diverse military training activities. Threatened and endangered species represent a particularly complex issue on DoD lands and surrounding areas as urban encroachment continues to reduce undeveloped environments adjacent to facility boundaries (MacDonald and Lozar 2006). The presence of at risk species that are potential candidates for future listing may result in increased restrictions on training areas. There is a very limited documentation of the abundance, distribution, and spatial extent of SAR on DoD lands due to sparse and sporadic observations of individuals. A detailed understanding of habitat requirements for many of the at-risk species is also lacking. Therefore, accurate and repeatable methods, including the use of remote sensing technologies, are required to detect and monitor SAR and their habitats on military installations.

Objectives

The objectives of this study were to:

1. Assess the utility of currently available remote sensing technologies to detect, delineate, and/or monitor a list of 63 at-risk plant and animal species distributed within 29 U.S. Army training and testing installations
2. Identify and prioritize those SARs with the greatest potential for detection, mapping, and monitoring with remotely sensed data
3. Present a prototype plan for research case studies to acquire, analyze, and validate remote sensing methods to detect, map, and monitor such species and their habitats.

Approach

Sixty-three at-risk species were identified and prioritized based on their potential impacts to the installation's training mission if they were to be listed as either threatened or endangered. Thirty-three of the SARs were animals, and included insects, mollusks, fish, reptiles, amphibians, birds, and mammals. The remaining 30 SARs were plant species, and included a variety of annual and perennial herbs, as well as woody shrubs and several tree species. The species list was first stratified using the location of the 29 Army installations within Bailey's Ecosystem Divisions (Bailey 1994). Within each ecosystem division, the at-risk flora and fauna and their habitats were assessed for detectability with all commercially available remotely sensed data sources, including both airborne and space imaging systems. Descriptions of species and their habitats were compiled using primarily web-based searches. Finally, each species was ranked according to the potential utility of remote sensing for quantifying their distribution within their described habitats or for delineating their habitats.

Mode of technology transfer

The information and assessments provided in this report are intended to identify information gaps associated with landscape-wide assessment of DoD critical SAR through the use of remote sensing technologies. Based on the recommendations in this report, it is anticipated that additional applied research will be focused on assessment of SAR with the greatest potential for spatial characterization with remotely sensed data.

This report will also be made accessible through the World Wide Web (WWW) at URL: http://www.cecer.army.mil

2 Methods

Using the DoD priority list of 63 at-risk species distributed over the 29 Army installations, the initial step was to simply segregate the species by plant vs. animal, then to stratify by location. A spatial stratification was completed by locating each installation within Bailey's Ecosystem Divisions (Bailey 1994). Figure 1 shows the 19 Baileys Ecosystem Divisions for the 48 conterminous United States.

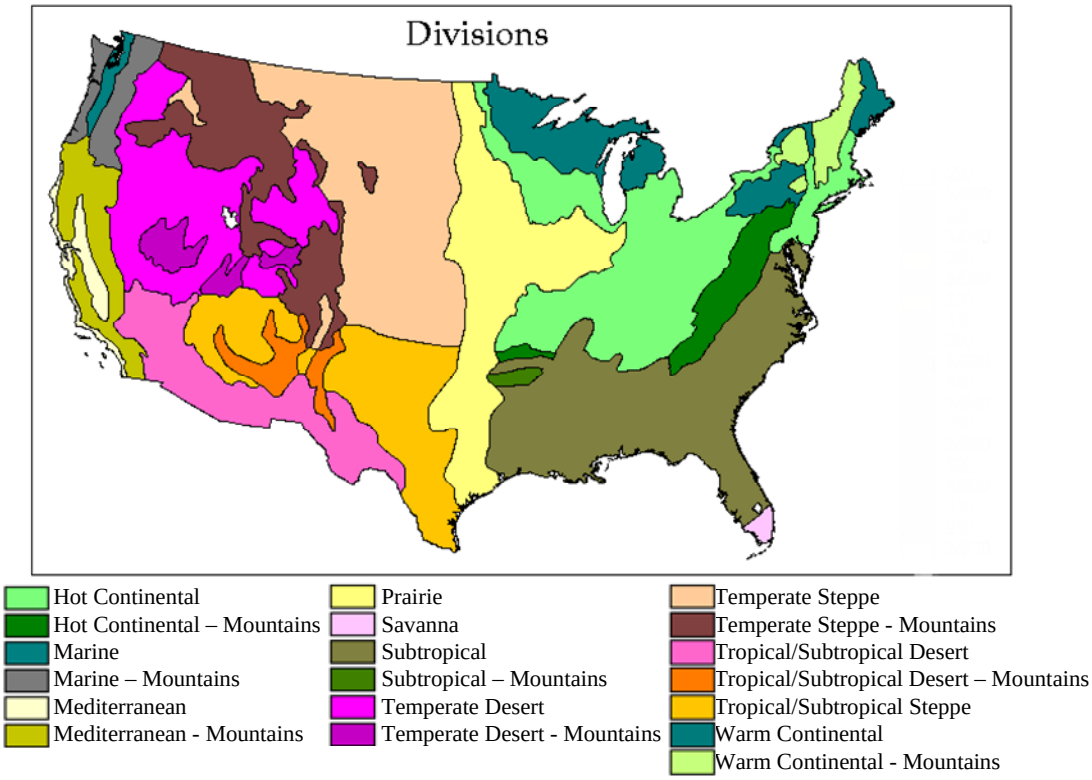

Figure 1. Bailey's ecosystem divisions for the lower 48 states

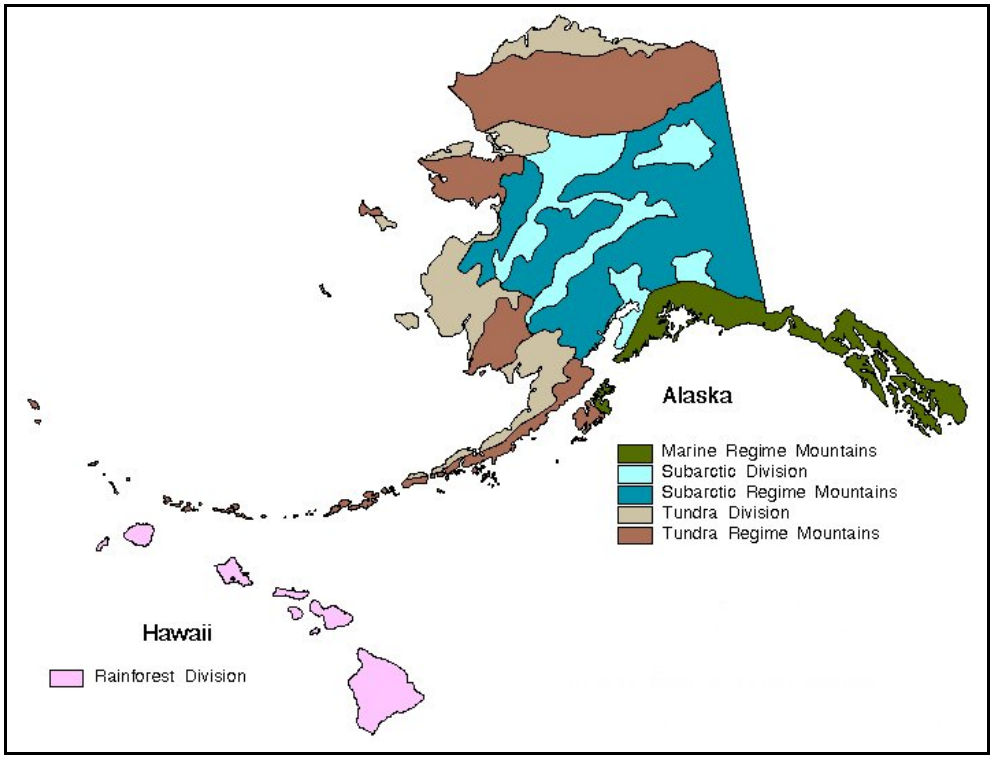

Figure 2. Bailey's ecosystem divisions for Alaska and Hawaii.

Table 1. List of the 29 Army installations and the State where each is located.

Installation Name	State
Camp Atterbury	Indiana
Camp Grayling	Michigan
Camp Roberts	California
Camp Shelby	Mississippi
Camp Swift	Texas
Dugway Proving Ground	Utah
Fort Bliss	Texas
Fort Bragg	North Carolina
Fort Carson	Colorado
Fort Dix	New Jersey
Fort Gordon	Georgia
Fort Hood	Texas
Fort Indiantown Gap	Pennsylvania
Fort Irwin	California
Fort Lewis	Washington

Installation Name	State
Fort McClellan	Alabama
Fort McCoy	Wisconsin
Fort Pickett	Virginia
Fort Polk	Louisiana
Fort Riley	Kansas
Fort Stewart	Georgia
Fort Wainwright-Donnelly TA	Alaska
Kahuku TA	Hawaii
Kawailoa TA	Hawaii
Makua Military Reservation	Hawaii
Orchard Training Site	Idaho
Schofield Barracks	Hawaii
White Sands Missile Range	Texas
Yakima Training Center	Washington

Bailey's ecosystem division descriptions

The following sub-sections provide a brief description of each ecosystem division, the list of species, and within each division, their associated Army installation.

Subtropical division

> The humid subtropical climate, marked by high humidity (especially in summer) and the absence of really cold winters, prevails in Southern Atlantic and Gulf Coast States. (Bailey 1994)

Figure 3 shows the subtropical ecosystem division (which covers all of the southeastern states and the mid-Atlantic states), and the approximate locations of the six military installations.

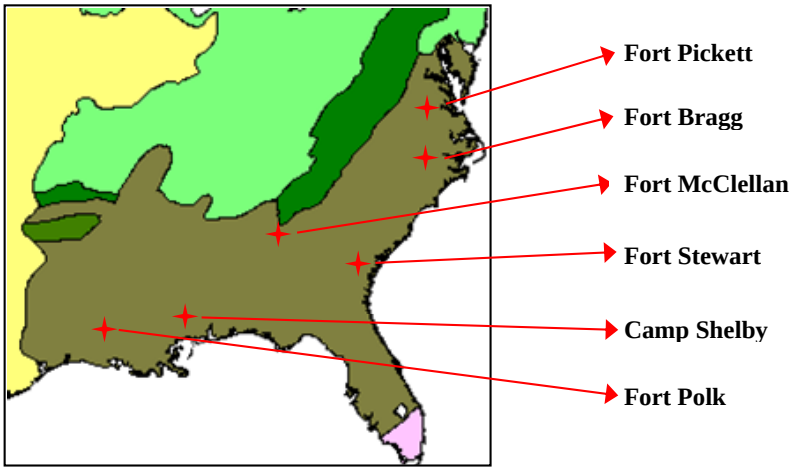

Figure 3. Extent of Subtropical Ecosystem Division and locations of six military installations.

A total of 15 species were accessed within these six facilities. Table 2 lists the fauna and the flora for each base.

Hot continental

> South of the warm continental climate lies another division in the Humid Temperate Domain, one with hot summers and cool winters. The boundary between the two is the isotherm of 72 °F (22 °C) for the warmest month. In the warmer sections of the Hot Continental Division, the frost-free or growing season continues for 5 to 6 months, in the colder sections only 3 to 5 months. Snow cover is deeper and lasts longer in the northerly areas. (Bailey 1994)

Table 2. At-risk species within the Subtropical Ecosystem Division.

Known Installation	State	Species Type	Common Name	Scientific Name
Fort McClellan	AL	fish	coldwater darter	*Etheostoma ditrema*
Camp Shelby	MS	crustacean	Camp Shelby burrowing crayfish	*Fallicambarus gordoni*
Fort Pickett	VA	mollusk	Atlantic pigtoe	*Fusconaia masoni*
Fort Polk	LA	reptile	Louisiana pine snake	*Pituophis ruthveni*
Fort Stewart	GA	reptile	Southern hognose snake	*Heterodon simus*
Fort Stewart	GA	amphibian	striped newt	*Notophthalmus perstriatus*
Fort Stewart	GA	reptile	mimic glass lizard	*Ophisaurus mimicus*
Fort Bragg	NC	woody shrub	Georgia leadplant	*Amorpha georgiana var georgiana*
Fort Bragg	NC	herbaceous	Sandhills milk-vetch	*Astragalus michauxii*
Fort Bragg	NC	herbaceous	Sandhills lilly	*Lillium pyrophilum*
Fort Bragg	NC	herbaceous	Well's pyxie-moss	*Pyxidanthera brevifolia*
Fort Pickett	VA	herbaceous	Torrey's mountain mint	*Pycnanthemum torrei*
Fort Polk	LA	herbaceous	bog coneflower	*Rudbeckia scabrifolia*
Fort Stewart	GA	herbaceous	purple balduina	*Balduina atropurpurea*
Fort Stewart	GA	woody shrub/small tree	Georgia plume	*Elliottia racemosa*
Fort Stewart	GA	herbaceous	giant orchid	*Pteroglossaspis ecristata*

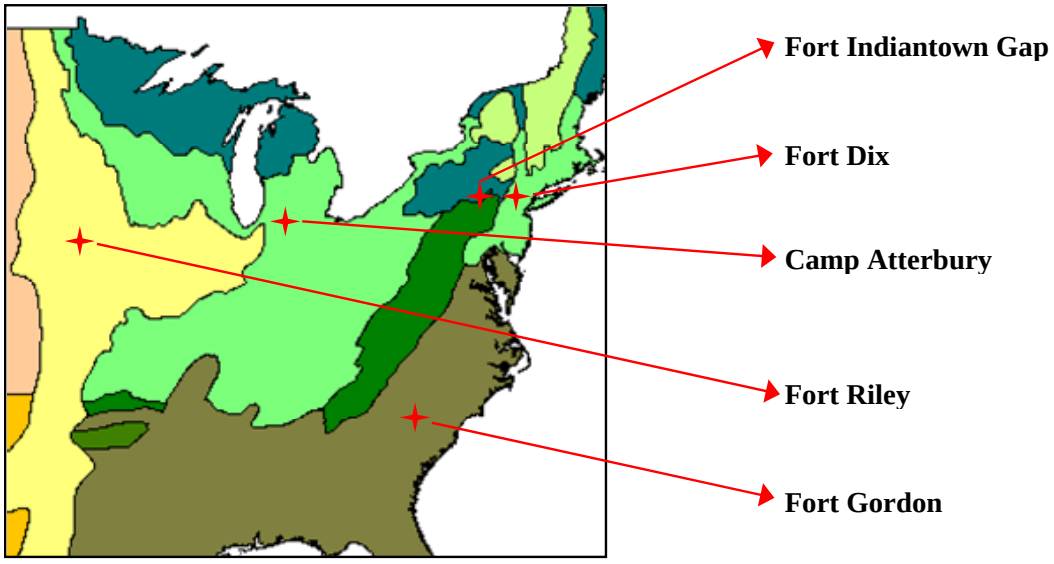

Figure 4. Extent of Hot Continental Ecosystem Division and locations of five installations. Fort Gordon lies within the Subtropical Division and Fort Riley is located within the Prairie Ecosystem Division.

Only three species were accessed within these five facilities (Figure 4). Table 3 lists the two animals and the one plant. Note that the regal fritillary butterfly and Pickering's morning glory are resident within two distinct ecosystem divisions.

Table 3. At-risk species within the Hot Continental Ecosystem Division.

Known Installation	State(s)	Species Type	Common Name	Scientific Name	Ecosystem Divisions
Camp Atterbury	IN	mollusk	rayed bean	*Villosa fabalis*	Hot Continental
Fort Indiantown Gap Fort Riley	PA, KS	insect	regal fritillary butterfly	*Speyeria idalia*	Hot Continental, Prairie
Fort Dix, Fort Gordon	NJ, GA	herbaceous	Pickering's morning glory	*Stylisma pickeringii var. pickeringii*	Subtropical, Hot Continental

Warm continental

South of the eastern area of the subarctic climate, in the region between latitude 40 and 55 N and from the continental interior to the east coast, lies the humid warm-summer continental climate. Located squarely between the source regions of polar continental air masses to the north and maritime or continental tropical air masses to the south, it is subject to strong seasonal contrasts in temperature as these air masses push back and forth across the continent. (Bailey 1994)

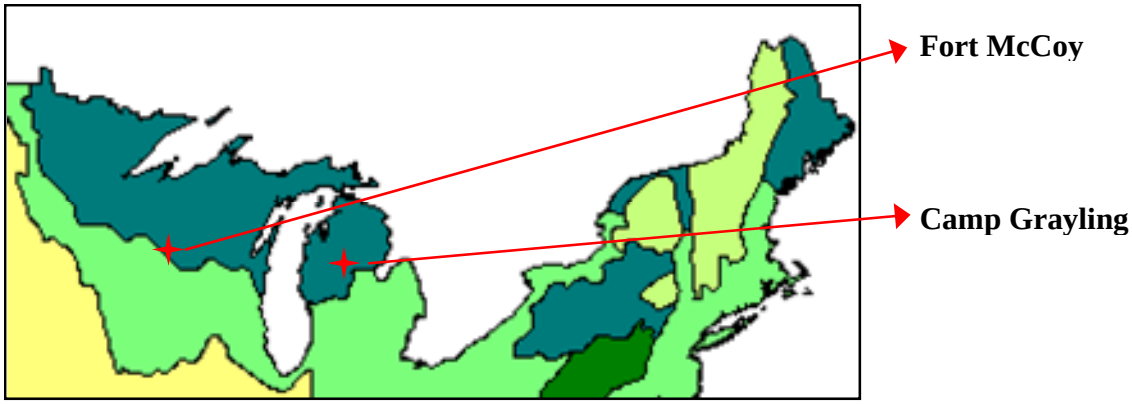

Figure 5. Extent of Warm Continental Division and locations of two Army installations.

Five species, all fauna, are found at two installations (Figure 5) within the Warm Continental Ecosystem Division (Table 4). Henslow's sparrow also inhabits Fort Riley in the Prairie Division (see below).

Table 4. At-risk species within the Warm Continental Ecosystem Division.

Known Installation	State(s)	Species Type	Common Name	Scientific Name	Ecosystem Divisions
Camp Grayling	MI	insect	Michigan bog grasshopper	*Appalachia arcana*	Warm Continental
Camp Grayling	MI	insect	dusted skipper	*Atrytonopsis hianna*	Warm Continental
Camp Grayling	MI	reptile	eastern massasauga	*Sistrurus catenatus catenatus*	Warm Continental
Fort McCoy	WI	insect	red-tailed prairie leafhopper	*Aflexia rubranura*	Warm Continental
Fort McCoy, Fort Riley	WI, KS	bird	Henslow's sparrow	*Ammodramus henslowii*	Warm Continental, Prairie

Prairie

> Prairies are typically associated with continental, mid-latitude climates that are designated as subhumid. Precipitation in these climates ranges from 20 to 40 inches per year, and is almost entirely offset by evapotranspiration. In summer, air and soil temperatures are high, soil moisture in the uplands is inadequate for tree growth, and deeper sources of water are beyond the reach of tree roots. Prairie forms a broad belt extending from Texas northward to southern Alberta and Saskatchewan. Forest and prairie mix in a transitional belt on the eastern border of the division. (Bailey 1994)

Three faunal species are found at Camp Swift, TX (Figure 6) within the Prairie Ecosystem Division (Table 5). Henslow's sparrow (see Table 4 above) and the regal fritillary butterfly (see Table 3 above) are found on Fort Riley, KS within the Prairie Division.

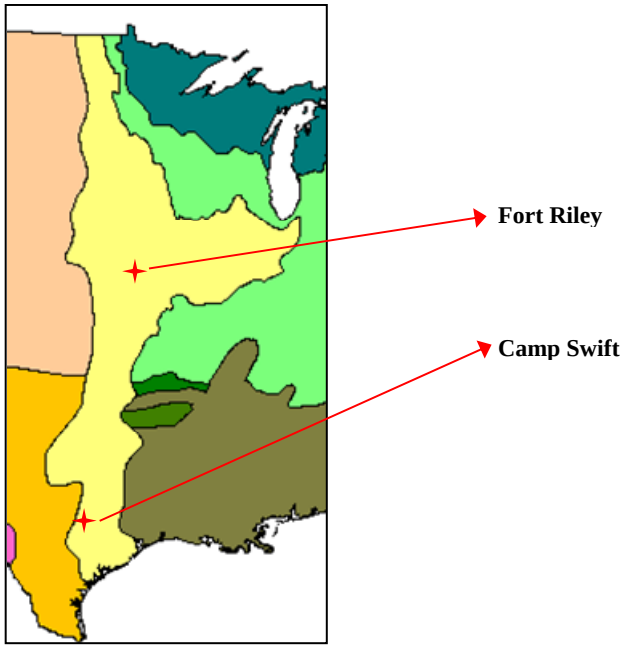

Figure 6. Extent of Prairie Ecosystem Division and locations of two Army installations.

Table 5. At-risk species within the Prairie Ecosystem Division.

Known Installation	State	Species Type	Common Name	Scientific Name
Camp Swift	TX	reptile	Texas horned lizard	*Phrynosoma cornutum*
Camp Swift	TX	insect	Comanche harvester ant	*Pogonomyrmex comanche*
Camp Swift	TX	amphibian	Southern crawfish frog	*Rana areolata areolata*

Tropical/subtropical desert

> South of the Arizona-New Mexico Mountains are the continental desert climates, which have not only extreme aridity, but also extremely high air and soil temperatures. Direct sun radiation is very strong, as is outgoing radiation at night, causing extreme variations between day and night temperatures and a rare nocturnal frost. Annual precipitation is less than 8 in (200 mm), and less than 4 in (100 mm) in extreme. (Bailey 1994)

Three installations are within the Tropical/Subtropical Desert Ecosystem Division (Figure 7). A total of six animals and three plants are distributed across the training facilities (Table 6).

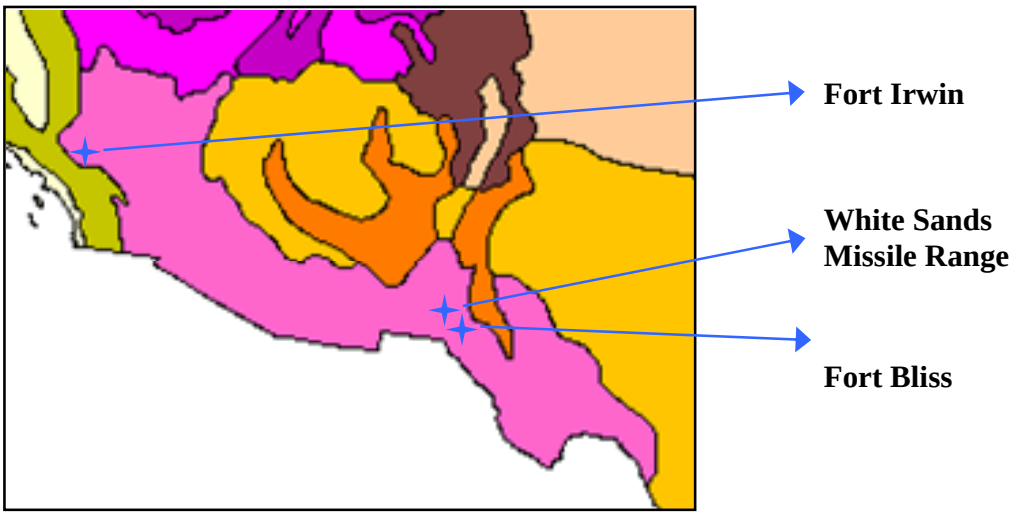

Figure 7. Extent of Tropical/Subtropical Desert Ecosystem Division and locations of three installations.

Table 6. At-risk species within the Tropical/Subtropical Desert Ecosystem Division.

Known Installation	State	Species Type	Common Name	Scientific Name
Fort Irwin	CA	mammal	Mohave ground squirrel	*Spermophilus mohavensis*
WSMR	NM	reptile	little white whiptail	*Aspidoscelis gypsi*
WSMR	NM	fish	White Sands pupfish	*Cyprinodon tularosa*
WSMR	NM	reptile	bleached earless lizard	*Holbrookia maculata ruthveni*
WSMR	NM	mammal	Oscura Mountains Colorado chipmunk	*Neotamias quadrivittatus oscuraensis*
WSMR	NM	reptile	White Sands prairie lizard	*Sceloporus undulatus cowlsi*
Fort Bliss	TX	herbaceous	Organ Mountain evening-primrose	*Oenothera organensis*
Fort Bliss	TX	herbaceous	Hueco Mountains rock daisy	*Perityle huecoensis*
Fort Irwin	CA	herbaceous	desert cymopterus	*Cymopteris deserticola*

Tropical/subtropical steppe

Tropical steppes border the tropical deserts on both the north and south, and in places on the east as well. Because of the local altitudes the plateaus and high plains, within what would otherwise be desert, have a semiarid steppe climate. Steppes on the poleward fringes of the tropical deserts grade into the Mediterranean climate in many places. In the United States, they are cut off from the Mediterranean climate by coastal mountains that allow tropical deserts to extend farther north. (Bailey 1994)

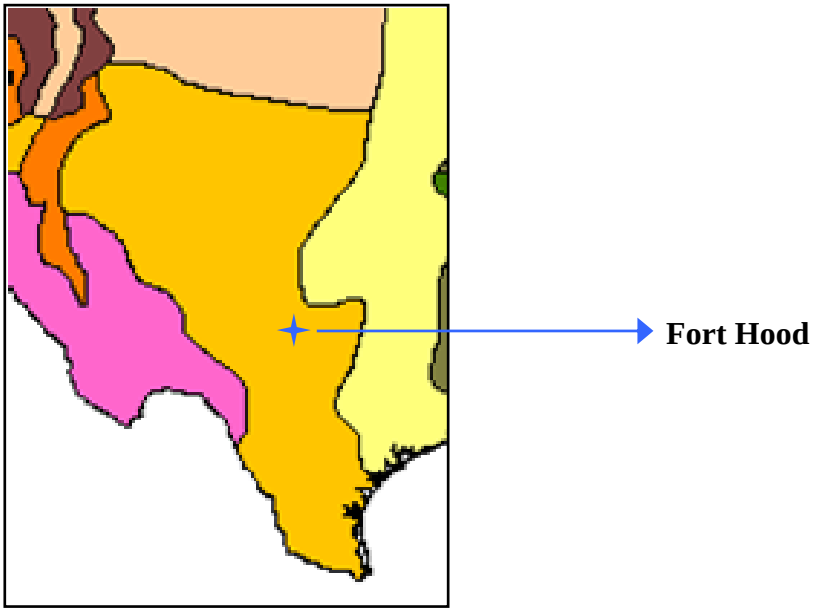

Figure 8. Extent of Tropical/Subtropical Desert Ecosystem Division and the location of Fort Hood, TX.

Fort Hood is the only installation situated within the Tropical Steppe Ecosystem Division (Figure 8). The specific SAR is a woody shrub, the Texabama croton (Table 7).

Table 7. At-risk species within the Tropical/Subtropical Steppe Ecosystem Division.

Known Installation	State	Species Type	Common Name	Scientific Name
Fort Hood	TX	woody shrub	Texabama croton (Alabama croton)	*Croton alabamensis var. texensis*

Temperate desert

> Temperate deserts of continental regions have low rainfall and strong temperature contrasts between summer and winter. In the intermountain region of the Western United States between the Pacific coast and Rocky Mountains, the temperate desert has characteristics of a sagebrush (Artemisia) semidesert, with a very pronounced drought season and a short humid season. Most precipitation falls in winter, despite a peak in May. Aridity increases markedly in the rain shadow of the Pacific mountain ranges. Even at intermediate elevations, winters are long and cold, with temperatures falling below 32 °F (0 °C). (Bailey 1994)

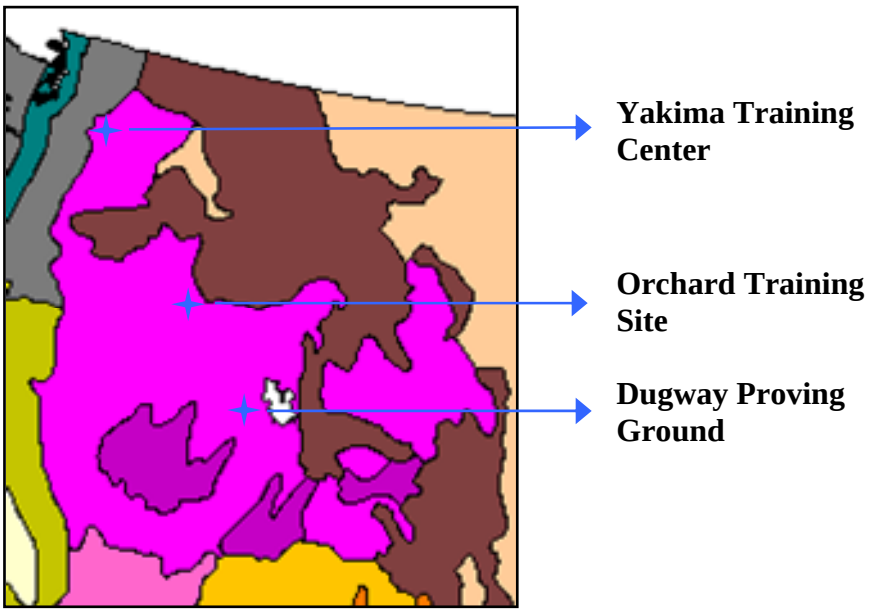

Figure 9. Extent of Temperate Desert Ecosystem Division and locations of three Army installations.

Three installations are located within the Temperate Desert Ecosystem Division (Figure 9) housing four at-risk species, including two animals and two plants (Table 8).

Table 8. At-risk species within the Temperate Desert Ecosystem Division.

Known Installation	State	Species Type	Common Name	Scientific Name
Dugway Proving Ground	UT	insect	Emmel's blue butterfly	*Euphilotes rita emmeli*
Yakima Training Center	WA	bird	Greater sage-grouse	*Centrocercus urophasianus*
Dugway Proving Ground	UT	herbaceous	Leo penstemon	*Penstemon leonardii var. patricus*
Orchard Training Site	ID	herbaceous	slickspot peppergrass	*Lepidium papilliferum*

Temperate steppe

Temperate steppes are areas with a semiarid continental climatic regime in which, despite maximum summer rainfall, evaporation usually exceeds precipitation. Trewartha (1968) classifies the climate as BSk; the letter k signifies a cool climate with at least 1 month of average temperatures below 32 °F (0 °C). Winters are cold and dry, summers warm to hot (see Appendix B, climate diagram for Colorado Springs, Colorado). The vegetation is steppe, sometimes called shortgrass prairie, and semidesert. Typical steppe vegetation consists of numerous species of short grasses

that usually grow in sparsely distributed bunches. Scattered shrubs and low trees sometimes grow in the steppe; all gradations of cover are present, from semidesert to woodland. Because ground cover is generally sparse, much soil is exposed. Many species of grasses and other herbs occur. Buffalo grass is typical of the American steppe; other typical plants are the sunflower and locoweed. (Bailey 1994)

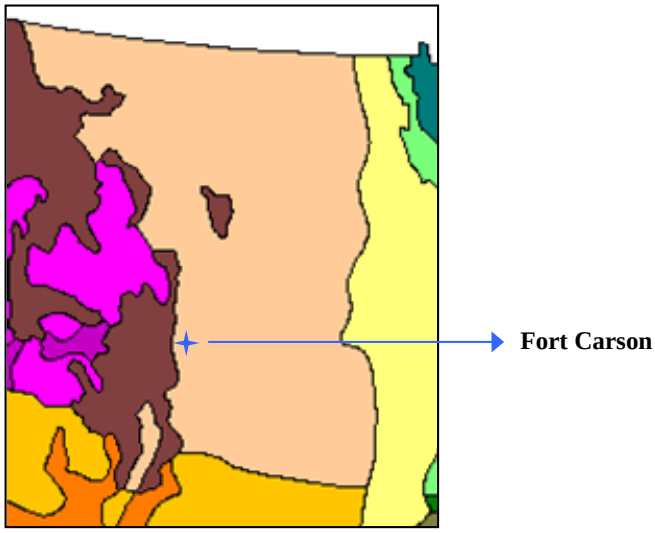

Figure 10. Extent of Temperate Steppe Ecosystem Division and the location of Fort Carson, CO.

Table 9. At-risk species within the Temperate Steppe Ecosystem Division.

Known Installation	State	Species Type	Common Name	Scientific Name
Fort Carson	CO	herbaceous	dwarf milkweed	*Asclepias uncialis*
Fort Carson	CO	herbaceous	Arkansas River feverfew	*Bolophyta tetraneuris*
Fort Carson	CO	herbaceous	golden blazing star	*Nuttalia chrysantha*

Mediterranean

Situated on the Pacific coast between latitudes 30 and 45 N. is a zone subject to alternate wet and dry seasons, the transition zone between the dry west coast desert and the wet west coast. (Bailey 1994)

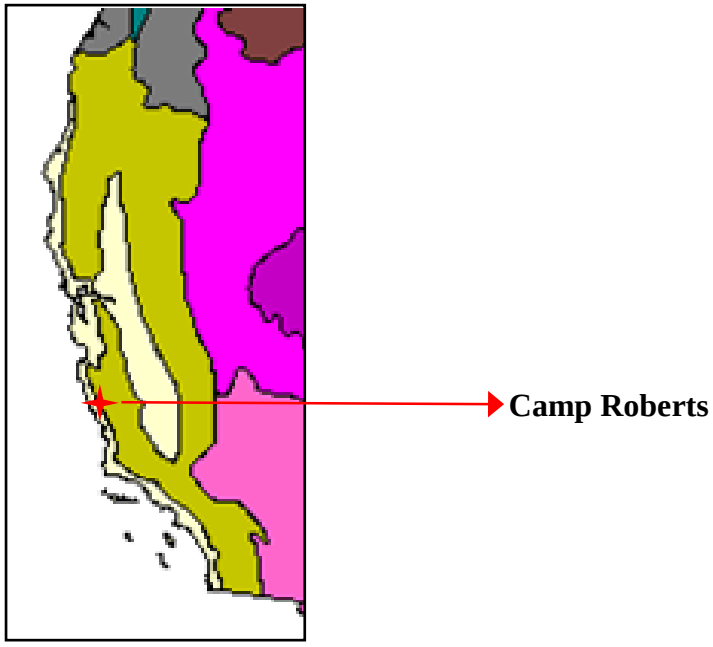

Figure 11. Extent of Mediterranean Ecosystem Division and the location of Camp Roberts, CA.

Camp Roberts (Figure 11), the only installation in the Mediterranean Ecosystem Division, provides habitat for one at-risk reptile (Table 10).

Table 10. At-risk species within the Mediterranean Ecosystem Division.

Known Installation	State	Species Type	Common Name	Scientific Name
Camp Roberts	CA	reptile	southwestern pond turtle	*Actinemys marmorata pallida*

Marine

Situated on the Pacific coast between latitudes 40 and 60 N. is a zone that receives abundant rainfall from maritime polar air masses and has a rather narrow range of temperatures because it borders on the ocean. (Bailey 1994)

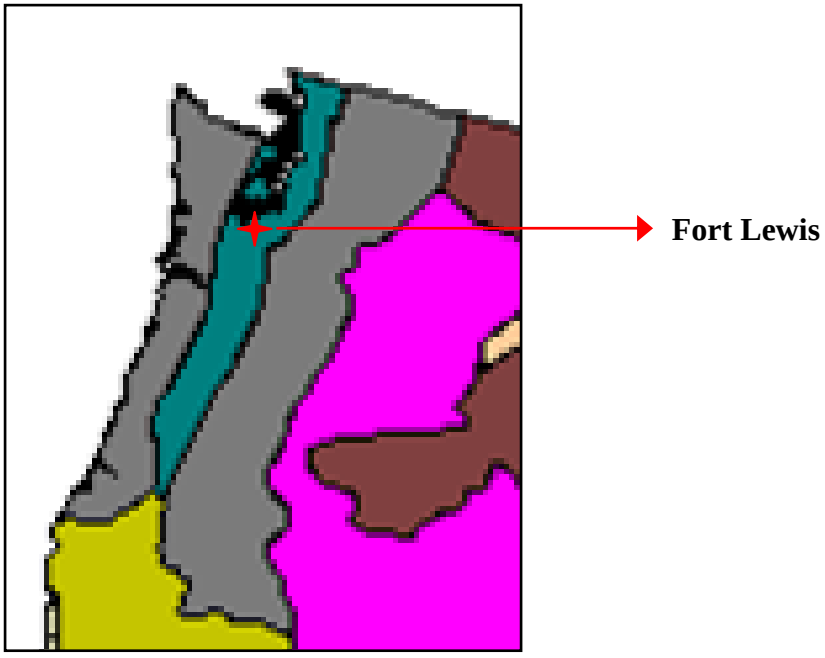

Figure 12. Extent of Marine Ecosystem Division and the location of Fort Lewis, WA.

Fort Lewis is the only facility in the Marine Ecosystem Division (Figure 12) and is home to four at-risk animal species (Table 11).

Table 11. At-risk species within the Marine Ecosystem Division.

Known Installation	State	Species Type	Common Name	Scientific Name
Fort Lewis	WA	insect	Mardon skipper	*Polites mardon*
Fort Lewis	WA	mammal	Mazama pocket gopher	*Thomomys mazama*
Fort Lewis	WA	bird	streaked horned lark	*Eremophila alpestris strigata*
Fort Lewis	WA	bird	Taylor's checkerspot	*Euphydryas editha taylori*

Subarctic

The source region for the continental polar air masses is south of the tundra zone between lat. 50 and 70 N. The climate type here shows very

great seasonal range in temperature; winters are severe, and the region's small amounts of annual precipitation are concentrated in the 3 warm months. This cold, snowy forest climate, referred to in this volume as the boreal subarctic type, is classified as E in the Koppen-Trewartha system. This climate is moist all year, with cool, short summers (see Appendix 2, climate diagram for Fort Yukon, Alaska). Only 1 month of the year has an average temperature above 50 °F (10 °C).

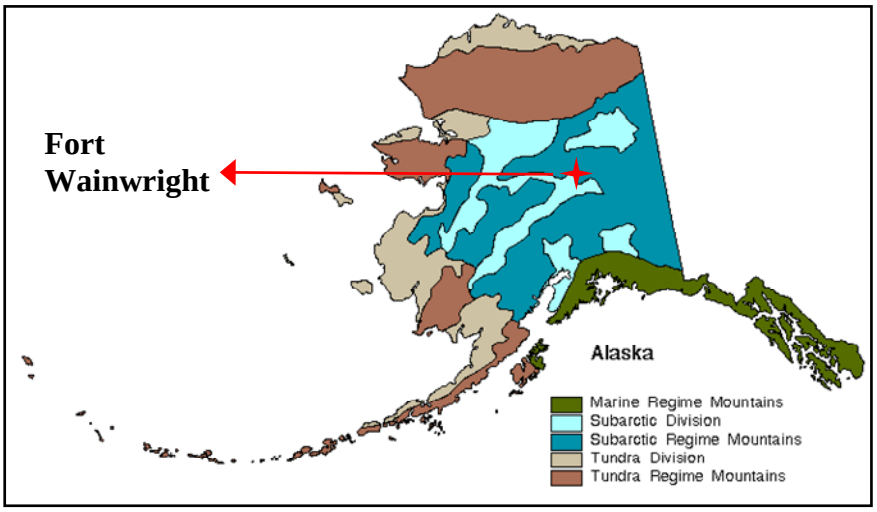

Figure 13. Extent of Subarctic Ecosystem Division and the location of Fort Wainwright, AK.

Fort Wainwright, including the Donnelly Training Area, is located in the Subarctic Ecosystem Division (Figure 13). One bird and two herbaceous plants are found within these training areas (Table 12).

Table 12. At-risk species within the Subarctic Ecosystem Division.

Known Installation	State	Species Type	Common Name	Scientific Name
Fort Wainwright-Donnelly TA	AK	bird	rusty blackbird	*Euphagus carolinus*
Fort Wainwright	AK	herbaceous	Tanana locoweed	*Oxytropis tananensis*
Fort Wainwright-Donnelly TA	AK	herbaceous	Alaska starwort	*Stellaria alaskana*

Rainforest

Between the equator and lat. 10 N. lies a region classified as wet equatorial or rainforest climate. Average annual temperatures are close to 80 °F (27 °C); seasonal variation is virtually imperceptible. Rainfall is heavy throughout the year, but monthly averages vary considerably due to seasonal shifts in the equatorial convergence zone and a consequent variation in air mass characteristics. (Bailey 1994)

The four Army installations within the Rainforest Ecosystem Division are located on the island of Oahu (Figure 14). Two insects and nine plant species are listed as SARs (Table 13).

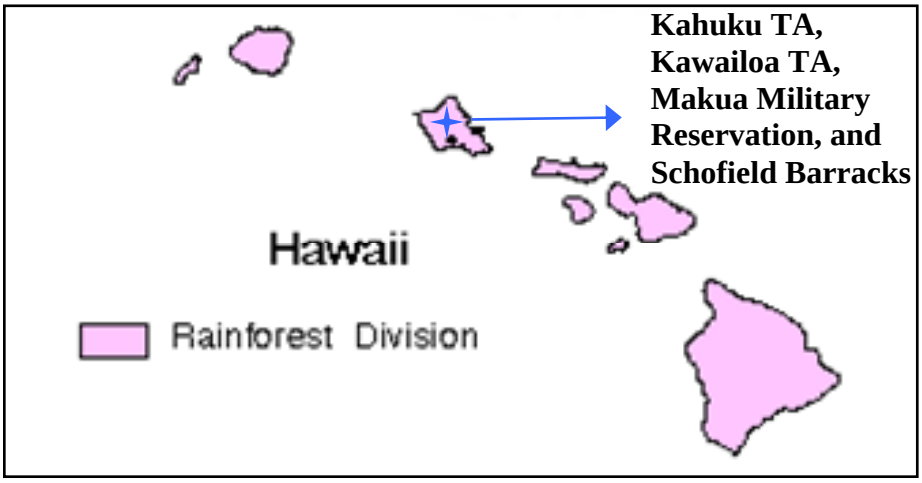

Figure 14. Extent of Rainforest Ecosystem Division and the location of the Army installations on O'ahu Island, HI.

Table 13. At-risk species within the Rainforest Ecosystem Division.

Known Installation	State	Species Type	Common Name	Scientific Name
Kawailoa TA	HI	insect	blackhook Hawaiian damselfly	*Megalagrion nigtohamatum nigrolineatum*
Schofield Barracks	HI	insect	crimson Hawaiian damselfly	*Megalagrion leptodemas*
Kahuku TA, Kawailoa TA, Makua Military Reservation, Schofield Barracks	HI	tree	Kaulu	*Pteralyxia macrocarpa*
Kawailoa TA	HI	woody shrub	(no common name)	*Hedyotis fluviatilis*
Kawailoa TA	HI	small tree	Alani	*Melicope hiiakae*
Kawailoa TA	HI	herbaceous	(no common name)	*Thelypteris boydiae*
Kawailoa TA, Makua Military Reservation, Schofield Barracks	HI	woody shrub	Pilo kea	*Platydesma cornuta var cornuta*
Kawailoa TA, Schofield Barracks	HI	herbaceous	Ohe	*Joinvillea ascendens ssp ascendens*
Kawailoa TA, Schofield Barracks, Schofield Barracks (ER)	HI	small woody shrub	haha	*Cyanea calycina*
Makua Military Reservation	HI	parasitic subshrub on Soapberry tree branches	Hulumoa	*Korthalsella degeneri*
Makua Military Reservation	HI	tree	Aiea	*Nothecestrum latifolium*

Ranking the remote sensing potential

A thorough web-based search was performed for each species to gather descriptive information. For most of the 63 list plants and animals an adequate amount information was gathered to evaluate the following characteristics:

- detailed physical/physiological descriptions
- typical life cycle and behavioral patterns (e.g., migration, hibernation, estivation)
- documented habitat requirements
- extent of current, and sometimes past, known range(s).

Where possible, multiple websites were found for each species to provide at least a minimum of quality assurance through the corroboration of two or more sources. In some cases, the species was described as very rare with little quantitative information defining its habitat, social behavior, and current range.

Images for each plant and animal were also located and copied from one or more websites. The images ranged from field photographs of the species in its natural setting to photos of pressed plant species to artist sketches. In three cases, no images of the specific species, or images of any related species, were located. These included:

- Hueco Mountains rock daisy (Fort Bliss, TX)
- Emmels's Blue butterfly (Dugway Proving Ground, UT)
- Boyd's maiden fern (Island of O'ahu, HI).

In four other cases, where images of the species-at-risk were unavailable, pictures of a closely related species (i.e., in the same genius and presumed to have similar phenological characteristics) were substituted. These include:

- Oscura Mountains Colorado Chipmunk (White Sands Missile Range, TX)
- Hulumosa (Island of O'ahu, HI)
- 'Ohe (Island of O'ahu, HI)
- *Melicope hiiake* (Island of O'ahu, HI).

Finally, maps and satellite images of each of the 29 Army installations were captured as simple screen grabs exclusively from Google Maps. The purpose of acquiring both the area maps and the true-color satellite images was to allow for a visual representation of earth surface features (e.g., vegetative cover, surface hydrology, surficial geology, and urban/suburban zones) that characterize the lands within and adjacent to each installation.

The species descriptions, together with images and maps of the installations, were used to assess the utility of remotely sensed data for the detection and monitoring of the 63 at-risk species. The remote sensing potential rankings were based on a simple five-point scale:

1 = very low
2 = low
3 = moderate
4 = high
5 = very high.

The complete array of available remotely sensed data sources were considered when developing a remote sensing score for each species. The list of potential sensor types included:

- Airborne Imaging Systems:
  - Digital Aerial Photography – Aerial photography typically provides the highest spatial resolution, remotely sensed data source for most earth surface mapping applications. Post-processing the individual frames (i.e., color balancing, mosaicking, and geometric registration) is time consuming, and therefore potentially expensive, over large areas. Aerial photo mosaics are best suited for manual interpretation and are generally limited to three-band spectral combinations: true-color or false-color (color infrared) composites.
  - Multispectral Airborne Scanners – Similar to digital aerial photography, airborne multispectral systems typically offer four or more spectral bands. These systems may produce individual frames or acquire imagery with pushbroom scanner technology. The radiometric fidelity of true multispectral sensors offers greater flexibility with image post-processing and classification using digital image processing software (e.g., Leica Imagine, ITT-ENVI).
  - Hyperspectral Airborne Scanners – Commercial airborne hyperspectral imaging systems are continuing to improve data quality through enhanced data acquisition and image post-processing

techniques. Captured using pushbroom scanner systems, airborne hyperspectral imagery offers a broad spectral range for earth surface mapping applications. Radiometric (i.e., reflectance) calibration, while becoming easier with recent enhancements in commercial image processing software, typically requires the collection of expensive ground-based spectral measurements. However, once hyperspectral imagery has been accurately calibrated and geometrically registered, it potentially provides the best remotely sensed data source for accurate detection and detailed delineation of earth surface features.

- Airborne Thermal Sensors – Remote sensing systems that record passive thermal emissions are generally used to detect and monitor phenomena that have unique heat absorbing and remitting properties. Examples include: thermal properties of aquatic systems (e.g., large freshwater bodies, marine, oceanic), snow and ice mapping, atmospheric phenomena, and surficial geologic mapping. Thermal remote sensing requires careful data acquisition planning and execution to ensure that the images capture the feature of interest when its thermal emissivity is distinctly different from the thermal emission properties of adjacent objects. Ground-based emission spectra are an essential, and potentially expensive, component of a thermal image application. Digital processing methods are also unique to thermal images, requiring dedicated algorithms available in advanced imaging software.
- Airborne Synthetic Aperature Radar (SAR) Sensors – Radio Detection and Ranging (radar) sensors use an active microwave pulse of energy, typically emitted at an oblique angle relative to nadir, to produce images that quantify earth surface texture. When combined with suitable optical imagery, radar data can enhance the identification and discrimination of both natural and man-made surface features.
- Airborne LIDAR Sensors – Light Detection and Ranging (LIDAR) sensors use an active laser pulse, fired nadir, to quantify the elevation of earth objects. LIDAR raw data, in the form of a point cloud (i.e., a cluster of 3-dimensional points), is typically used to generate high resolution digital elevation models (DEM) that provide detailed earth surface textural information.

- Satellite Imaging Systems:
  - Multispectral Satellite Sensors – Commercial multispectral satellite imagery continues to offer one of the most cost-effective sources of remotely sensed imagery for accurate landcover mapping. Both medium and high spatial resolution sensors acquire four or more spectral bands over large to very large areas. Current digital image processing software has been designed to rapidly input, post-process, and classify multispectral data from numerous satellite sensors.
  - Satellite Thermal Sensors – As with the airborne thermal imagers, satellite systems that collect thermal emissions require unique processing methods for the identification and mapping of surface features. Spatial resolutions provided by thermal satellite data is typically two to three times greater than coincident optical sensor data.
  - Satellite Synthetic Aperature Radar (SAR) Sensors – Like the airborne systems, SAR data from satellite platforms provides earth surface textural information, but with a more coarse spatial resolution.

While the evaluation methods were not absolutely consistent for all species, the following general thought process was employed to develop a remote sensing potential score:

1. *Can an individual, or groups (also patches) of individuals, be directly detected and identified using a remote sensing device?*
   For the listed animal species, the answer to this question was universally "No." The largest animal investigated was the greater sage-grouse. Even very high spatial resolution aerial photograph is likely incapable of capturing images of an individual sage-grouse. A number of the animal species are subterranean with no opportunity for image detection. Likewise, most of the listed plants are very small and tend not to grow in clumps large enough for accurate detection by even the highest resolution optical imagery. Several species may exist in large clumps, but inhabit the understory in a forested environment and will typically be undetectable beneath a mature overstory canopy. Several of the overstory tree species, specifically those species within the Rainforest ecosystem division, are perhaps detectable with high spatial/spectral resolution imagery, but exist only as a few (i.e., < 100), widely scattered individuals intermixed in a dense tropi-

cal rainforest canopy and were ranked with a very low remote sensing potential.

2. *Does a unique habitat exist for the species?*
   In several cases, past habitat investigations reported that a species was associated with a distinct vegetative community. Several species were documented to inhabit terrain within limited elevation ranges, over (or beneath) distinct soil types or surficial geologic material, or within (and adjacent to) confining aquatic/sub-aquatic/semi-aquatic environments. For a few species it was presumed that the unique, and perhaps easily detectable, habitat was likely already thoroughly mapped due to that habitat's current strict conservation and protection management requirements.
3. *For those species that have some remote sensing potential, will use of airborne or satellite sensors offer any substantial benefits for detection and monitoring over traditional field-based sampling methods?*
   This is an important consideration for those species that exist in a readily detectable habitat, but remain undetectable as individuals or patches. Certainly remotely sensed imagery, combined with geospatial processing tools, will accurately delineate potential habitat, but will not add significant value to the subsequent field investigations required to confirm and document species occurrences.

3 Results

Table 14 summarizes a final ranking that reflects the potential utility of remote sensing for assessing each of the 63 DoD priority SAR plant and animal species.

Table 14. Remote sensing rankings for each species.

Known Installation	State	Common Name	Scientific Name	Ecosystem Division(s)	Remote Sensing Ranking[1]
Fort McClellan	AL	coldwater darter	*Etheostoma ditrema*	Subtropical	1
Camp Shelby	MS	Camp Shelby burrowing crayfish	*Fallicambarus gordoni*	Subtropical	2
Fort Pickett	VA	Atlantic pigtoe	*Fusconaia masoni*	Subtropical	1
Fort Polk	LA	Louisiana pine snake	*Pituophis ruthveni*	Subtropical	1 - 2
Fort Stewart	GA	Southern hognose snake	*Heterodon simus*	Subtropical	1
Fort Stewart	GA	striped newt	*Notophthalmus perstriatus*	Subtropical	2
Fort Stewart	GA	mimic glass lizard	*Ophisaurus mimicus*	Subtropical	1
Fort Bragg	NC	Georgia leadplant	*Amorpha georgiana var georgiana*	Subtropical	1 - 2
Fort Bragg	NC	Sandhills milkvetch	*Astragalus michauxii*	Subtropical	1 - 2
Fort Bragg	NC	Sandhills lilly	*Lillium pyrophilum*	Subtropical	1 - 2
Fort Bragg	NC	Well's pyxie-moss	*Pyxidanthera brevifolia*	Subtropical	1 - 2
Fort Pickett	VA	Torrey's mountain mint	*Pycnanthemum torrei*	Subtropical	1 - 2
Fort Polk	LA	bog coneflower	*Rudbeckia scabrifolia*	Subtropical	1 - 2
Fort Stewart	GA	purple balduina	*Balduina atropurpurea*	Subtropical	1 - 2
Fort Stewart	GA	Georgia plume	*Elliottia racemosa*	Subtropical	1 - 2
Fort Stewart	GA	giant orchid	*Pteroglossaspis ecristata*	Subtropical	1 - 2
Camp Atterbury	IN	rayed bean*	*Villosa fabalis*	Hot Continental	1
Fort Indiantown Gap, Fort Riley	PA, KS	regal fritillary butterfly	*Speyeria idalia*	Hot Continental, Prairie	1 - 2
Fort Dix, Fort Gordon	NJ, GA	Pickering's morning glory	*Stylisma pickeringii var. pickeringii*	Subtropical, Hot Continental	1 - 2
Camp Grayling	MI	Michigan bog grasshopper	*Appalachia arcana*	Warm Continental	1 - 2
Camp Grayling	MI	dusted skipper	*Atrytonopsis hianna*	Warm Continental	1 - 2
Camp Grayling	MI	eastern massasauga	*Sistrurus catenatus catenatus*	Warm Continental	1 - 2
Fort McCoy	WI	red-tailed prairie leafhopper	*Aflexia rubranura*	Warm Continental	1 - 2
Fort McCoy, Fort Riley	WI, KS	Henslow's sparrow	*Ammodramus henslowii*	Warm Continental, Prairie	2
Camp Swift	TX	Texas horned lizard	*Phrynosoma cornutum*	Prairie	2

[1]Remote Sensing Rankings: 1 = Very Low; 2 = Low; 3 = Moderate; 4 = High; 5 = Very High

Known Installation	State	Common Name	Scientific Name	Ecosystem Division(s)	Remote Sensing Ranking[1]
Camp Swift	TX	Comanche harvester ant	*Pogonomyrmex comanche*	Prairie	1
Camp Swift	TX	Southern crawfish frog	*Rana areolata areolata*	Prairie	1
Fort Irwin	CA	Mohave ground squirrel	*Spermophilus mohavensis*	Tropical/ Subtropical Desert	1
WSMR	NM	little white whiptail	*Aspidoscelis gypsi*	Tropical/ Subtropical Desert	2
WSMR	NM	White Sands pupfish	*Cyprinodon tularosa*	Tropical/ Subtropical Desert	3
WSMR	NM	bleached earless lizard	*Holbrookia maculata ruthveni*	Tropical/ Subtropical Desert	2
WSMR	NM	Oscura Mountains Colorado chipmunk	*Neotamias quadrivittatus oscuraensis*	Tropical/ Subtropical Desert	2
WSMR	NM	White Sands prairie lizard	*Sceloporus undulatus cowlsi*	Tropical/ Subtropical Desert	2
Fort Bliss	TX	Organ Mountain evening-primrose	*Oenothera organensis*	Tropical/ Subtropical Desert	2
Fort Bliss	TX	Hueco Mountains rock daisy	*Perityle huecoensis*	Tropical/ Subtropical Desert	2 - 3
Fort Irwin	CA	desert cymopterus	*Cymopteris deserticola*	Tropical/ Subtropical Desert	1 - 2
Fort Hood	TX	Texabama croton (Alabama croton)	*Croton alabamensis var. texensis*	Tropical/ Subtropical Steppe	1 - 2
Dugway Proving Ground	UT	Emmel's blue butterfly	*Euphilotes rita emmeli*	Temperate Desert	1 - 3
Yakima Training Center	WA	Greater sage-grouse	*Centrocercus urophasianus*	Temperate Desert	3
Dugway Proving Ground	UT	Leo penstemon	*Penstemon leonardii var. patricus*	Temperate Desert	1 - 2
Orchard Training Site	ID	slickspot peppergrass	*Lepidium papilliferum*	Temperate Desert	1 - 2
Fort Carson	CO	dwarf milkweed	*Asclepias uncialis*	Temperate Steppe	1 - 2
Fort Carson	CO	Arkansas River feverfew	*Bolophyta tetraneuris*	Temperate Steppe	2 - 3
Fort Carson	CO	golden blazing star	*Nuttalia chrysantha*	Temperate Steppe	2 - 3
Camp Roberts	CA	southwestern pond turtle	*Actinemys marmorata pallida*	Mediterranean	1
Fort Lewis	WA	Mardon skipper	*Polites mardon*	Marine	1 - 2
Fort Lewis	WA	Mazama pocket gopher	*Thomomys mazama*	Marine	2
Fort Lewis	WA	streaked horned lark	*Eremophila alpestris strigata*	Marine	3
Fort Lewis	WA	Taylor's checkerspot	*Euphydryas editha taylori*	Marine	2
Fort Wainwright-Donnelly TA	AK	rusty blackbird	*Euphagus carolinus*	Subarctic	2
Fort Wainwright	AK	Tanana locoweed	*Oxytropis tananensis*	Subarctic	1 - 2
Fort Wainwright-Donnelly TA	AK	Alaska starwort	*Stellaria alaskana*	Subarctic	1 - 2

[1]Remote Sensing Rankings: 1 = Very Low; 2 = Low; 3 = Moderate; 4 = High; 5 = Very High

Known Installation	State	Common Name	Scientific Name	Ecosystem Division(s)	Remote Sensing Ranking[1]
Kawailoa TA	HI	blackhook Hawaiian damselfly	*Megalagrion nigtohamatum nigrolineatum*	Rainforest	2
Schofield Barracks	HI	crimson Hawaiian damselfly	*Megalagrion leptodemas*	Rainforest	2
Kahuku TA, Kawailoa TA, Makua Military Reservation, Schofield Barracks	HI	Kaulu	*Pteralyxia macrocarpa*	Rainforest	1
Kawailoa TA	HI	(no common name)	*Hedyotis fluviatilis*	Rainforest	1
Kawailoa TA	HI	(no common name)	*Melicope hiiakae*	Rainforest	1 - 2
Kawailoa TA	HI	Boyd's Maiden Fern	*Cyclosorus boydiae*	Rainforest	1 - 2
Kawailoa TA, Makua Military Reservation, Schofield Barracks	HI	Pilo kea	*Platydesma cornuta var cornuta*	Rainforest	1 - 2
Kawailoa TA, Schofield Barracks	HI	Ohe	*Joinvillea ascendens ssp ascendens*	Rainforest	1 - 2
Kawailoa TA, Schofield Barracks, Schofield Barracks (ER)	HI	haha	*Cyanea calcina*	Rainforest	1 - 2
Makua Military Reservation	HI	Hulumoa	*Korthalsella degeneri*	Rainforest	1 - 2
Makua Military Reservation	HI	Aiea	*Nothecestrum latifolium*	Rainforest	1 - 2

[1]Remote Sensing Rankings: 1 = Very Low; 2 = Low; 3 = Moderate; 4 = High; 5 = Very High

4 Summary and Recommendations

Using the methodology described in the previous section for ranking each species, seven flora and fauna species were determined to have a remote sensing probability ranking greater than 2 (low potential).

The three floral species include:

- Arkansas River feverfew (*Bolophyta tetraneuris*)
- Golden Blazing Star *(Nuttallia chrysantha*)
- Hueco Mountains Rock Daisy (*Perityle huecoensis*).

The four animal species include:

- White Sands pupfish (*Cyprinodon Tularosa*)
- Greater Sage Grouse (*Centrocercus urophasianus*)
- Streaked Horned Lark (*Eremophila alpestris strigata*)
- Emmel's Blue Butterfly (*Euphilotes rita emmeli*).

A brief summary of the data acquisition (image and field data) and image analysis methods that would likely be used to map each species is presented below.

Arkansas River feverfew (*Bolophyta tetraneuris*, also *Parthenium tetraneuris*)

Arkansas River feverfew is a small flowering plant in the Aster family that exhibits mat-forming growth characteristics (Figure 15). *B. tetraneuris* inhabits barren, light colored shale and limestone benches and knolls in and around Fort Carson, CO within an elevation range of 1,645 to 1750 m. The potential for directly mapping Arkansas River feverfew individuals is very low due to its extremely small size. However, its unique position on the landscape and very limited geographic range suggest that a combined remote sensing/GIS habitat model may effectively delineate habitat of Arkansas River feverfew.

Figure 15. Arkansas River feverfew. (Colorado Natural Heritage Program, Rare Plant Field Guide. www.cnhp.colostate.edu/rareplants/plants/-Photos/large/PDAST6V090.gif).

The image and geospatial data inputs required to build an accurate habitat model must address both the confining elevation range of *B. tetraneuris* and the unique surface characteristics associated with the light-colored shale and limestone barrens. An archive 30 m EM, available from the USGS, could be used to segment the 1,645 to 1750 m elevation range. Existing medium scale soils, geology, and vegetation type maps could further define the potential range of barren sites. Archival commercial high-resolution multispectral satellite imagery, with limited spectral resolution (but with broad area coverage) could also be used to identify the light-toned barrens.

Full-range (400 to 2500 nm), airborne hyperspectral imagery would provide the optimal electro-optical imaging source for identifying and delineating the unique reflectance properties (i.e., the light-colored surface characteristics) of the barrens. Specifically, the short-wave infrared (SWIR) region of the electromagnetic spectrum (~1100 to 2500 nm) provides the discriminatory information associated with surficial geologic mapping. Furthermore, many of the sites known to support *B. tetraneuris* have been disturbed (e.g., road construction, training impacts). The unique spectral properties of these disturbed sites could be captured by the hyperspectral imagery. Micro-relief characteristics of the shale and limestone barrens could be captured with a high-resolution LIDAR-derived DEM.

This applied research effort would attempt to fuse surface spectral data (multispectral and hyperspectral), surface textural information, broad area terrain characteristics and ground-based vegetative inventory to identify and accurately delineate the unique habitat of *B. tetraneuris*. Several modeling techniques could be investigated, including: standard multivariate discriminant analysis (i.e., supervised classification) using all available raster and vector geospatial data layers, weighted decision tree analysis, or deterministic modeling where each terrain-based variable has defined parameter ranges.

Golden Blazing Star (*Nuttallia chrysantha*)

Golden Blazing Star (Figure 16) is a yellow-flowered member of the *Loasaceae* (Stickleaf family). The plants stand about 20 to 75 cm tall and support bright yellow flowers that open at about 6 p.m. and remain open until about 9 p.m.. *N. chrysantha* can be found on barren slopes of limestone, shale, or clay, within an elevation range of 1550 to 1750 m in Fremont and Pueblo Counties, CO. It is a narrowly restricted edaphic endemic that occurs on various members of the Niobrara shale formation over a 50 km long corridor in the Arkansas River Valley from Canyon City to Pueblo. *N. chrysantha* inhabits the same unique ecological niche as the Arkansas River feverfew. Therefore, model-based habitat maps this at-risk plant species could be developed using the data layers and methods described above for *B. tetraneuris*.

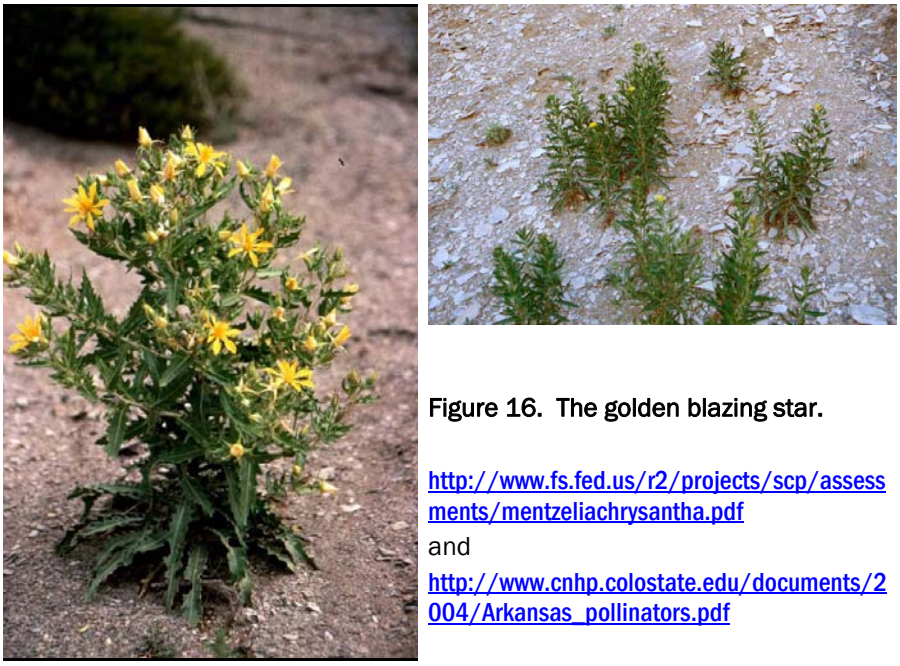

Figure 16. The golden blazing star.

http://www.fs.fed.us/r2/projects/scp/assessments/mentzeliachrysantha.pdf
and
http://www.cnhp.colostate.edu/documents/2004/Arkansas_pollinators.pdf

Hueco Mountains Rock Daisy (*Perityle huecoensis*)

Hueco Mountains Rock Daisy is a small perennial or subshrub that stands only 10 to 20 cm tall. Its habitat is restricted to dry limestone rock outcrops in the Hueco Mountains near El Paso, TX. It almost exclusively grows on north or northeast facing slopes and north facing, vertical limestone cliffs within relatively narrow, deep, somewhat mesic canyons. Few other species occur on these cliffs. *P. huecoensis* is currently known to exist in two canyons in the Hueco Mountains on Fort Bliss Military Reservation, where there are an estimated total of 700-800 plants.* No images of the *P. huecoensis* were found.

The moderate potential for mapping Hueco Mountains Rock Daisy habitat is due primarily to its unique position on the landscape as well as its very limited geographic range. This species is very similar to the Arkansas River feverfew and Golden Blazing Star described above in that it occupies a fairly unique landscape position within its known range. *P. huecoenisis* sites could be mapped using a combination of moderate to high-resolution digital terrain data and high spatial resolution multispectral imagery combined in a remote sensing/GIS habitat model. The utility of hyperspectral imagery within this species' habitat is limited since it is the only plant found at these sites and because the rock daisy does not appear to prefer a specific soil type. Field data would be required to build and refine a spatially explicit habitat model and to quantify model accuracy.

Greater Sage Grouse (*Centrocercus urophasianus*)

The Greater Sage Grouse, the largest grouse in North America (Figure 17), is found in shrub-steppe and meadow-steppe habitats. They are typically found in areas with low, rolling hills adjacent to valleys. They prefer medium-density sagebrush mixed with a variety of other plants. *C. urophasianus* are permanent residents in the sagebrush country of Washington, including lands within Yakima Training Center.

* http://www.nature.org/wherewework/northamerica/states/texas/files/-noplacebuttexas1.pdf; http://www.natureserve.org/explorer//servlet/NatureServe-?searchName=Perityle+huecoensis)

Figure 17. The greater sage grouse.

Primary image data acquisition requirements for developing a remote sensing/GIS habitat model include high-resolution multispectral satellite imagery. Airborne hyperspectral imagery may enhance the spectral separability of the sagebrush plant communities, as compared to four-band satellite imagery, but at a much higher acquisition and processing cost. Because the Greater Sage Grouse is found in low rolling hills, a relatively high resolution DEM would be required to accurately characterize those landforms. LIDAR data would likely provide the best data source for accurate and precise surface terrain and vegetation textural information. Existing geospatial layers at the installation, including vegetation distributions, soils, geology, and hydrology, would be compiled and implemented in model development. Finally, comprehensive field data would be collected to characterize the landscape and vegetation associations that typify *C. urophasianus* habitat.*

Streaked Horned Lark (*Eremophila alpestris strigata*)

The streaked horned lark is a small, slender, long-winged bird with distinctive black "horns," which are actually feather tufts (Figure 18). This species is associated with bare ground or sparsely vegetated habitats. The primary native habitat for the streaked horned lark is gravelly, well drained prairie. They nest in grass seed fields, pastures, fallow fields, and wetland mudflats. Gravel roads or roadsides are another common location to find streaked horned larks.

* http://www.xmission.com/~cldavis/birds123.html
http://www.birdweb.org/birdweb/bird_details.aspx?id=119#wa_map

Figure 18. The Streaked Horned Lark.

The open, sparsely vegetated areas within Fort Lewis, WA have the potential to be mapped using high-resolution multispectral imagery. Other open (i.e., disturbed) habited sites, including gravel roads and areas adjacent to airport runways, can likely be identified and delineated using commercial satellite imagery. The lack of terrain-based influences on lark habitat, considering that well-drained prairie is relatively flat, suggests that digital elevation models would not be required in this habitat modeling research effort. However, ancillary earth data layers would likely be required, including: existing vegetation class maps, soils layer, geology map, and any information cataloging disturbances in the low-land prairie.*

White Sands pupfish (*Cyprinodon Tularosa*)

The White Sands pupfish is only 5.0 cm in total length (Figure 19). It is a non-migratory fish found only in the freshwater (brackish) river system within the Tularosa Valley in New Mexico. Specifically, it occurs in clear, shallow spring-fed marsh pools and saline creeks of persistent bodies of water within the White Sands Missile Range.

* http://wdfw.wa.gov/wlm/research/papers/streaked_horned_lark/graphics/streaked_horned_lark.jpg
http://www.fws.gov/oregonfwo/Species/Data/StreakedHornedLark/default.asp
http://www.sanjuans.org/pdf_document/Streaked%20horned%20lark%20petition.pdf

Figure 19. The White Sands Pupfish.

Based on the fact that *C. tularosa* is distributed within such a small geographic area, the potential to accurately map the riverine system within the xeric landscape of the Tularosa Valley is fairly good. Standard remote sensing techniques could easily be applied to high-resolution commercial satellite imagery to delineate persistent bodies of water within the White Sands Missile Range.

Image data acquisition requirements for developing a riverine system map include high-resolution multispectral satellite imagery. A medium to high resolution DEM help to define the hydrologic network that feeds the riverine system could also be used. Additionally, historical weather station data (including daily/monthly rainfall totals) could be compiled. The historical precipitation data could be analyzed to identify the wettest month of the year and define an optimal date range for satellite image acquisition. The objective would be to collect the multispectral imagery when the rivers, streams, and pools are at their annual maximum. Conversely, acquiring imagery during the month with typically the lowest water levels will potentially provide the extent of the refuge habitat for *C. Tularosa*.*

Emmel's Blue Butterfly (*Euphilotes rita emmeli*)

As described above, there is some potential for mapping the unique habitat associated with Emmel's Blue Butterfly. However, a more thorough literature review and assessment of the ecology of the Coin Buckwheat

* http://www.quercus.ac.uk/pages/rogowski/image008.jpg
http://www.fishbase.org/Summary/SpeciesSummary.php?id=3180

(*Eriogonum nummulare*) Association (Figure 20), is required to determine if a combined remote sensing/GIS terrain model could be used to accurately delineate this xeric vegetation type. Coin Buckwheat is found within a very narrow elevation range (1317 to 1424 m) and is identified as a component of the Rabbitbush (*Chrysothamnus spp.*) Vegetation Alliance. The Rabbitbush Alliance is the preferred larval feeding habitat of *E. rita emmeli*. Input and cooperation from the natural resource management staff at Dugway Proving Ground is critical to this initial evaluation.*

Figure 20. Coin Buckwheat – Eriogonum nummulare.

* http://www.doylegroup.harvard.edu/~carlo/JRL/31/PDF/31-057.pdf
http://www.funet.fi/pub/sci/bio/life/insecta/lepidoptera/ditrysia/papilionoidea/lycaenidae/polyommatinae/euphilotes/index.html; http://zipcodezoo.com/Animals/E/Euphilotes_rita_emmeli.asp
http://www.cecer.army.mil/techreports/hil_dug2/hil_dug2-06.htm

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14. ABSTRACT

The presence of species on military training lands that could potentially be listed as threatened or endangered as defined under the Endangered Species Act as Species at Risk (SAR) may result in increased training restrictions if they were to be listed. Accurate and repeatable remote sensing methods in combination with field surveys are required to quantify the presence, and to characterize and monitor the spatial extent of SAR or their habitats on military lands. A list of DOD priority SAR species that have greatest potential to impact the training mission were assessed to identify and prioritize those with greatest potential for detection, mapping, and monitoring with remotely sensed data. Seven species were identified with greatest potential and a prototype plan for research case studies to acquire, analyze, and validate remote sensing methods to detect, map, and monitor such species was provided.

15. SUBJECT TERMS

natural resource management, Species at Risk (SAR), remote sensing, Army installations

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